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No. 608

THE USE OF ELEKTRON METAL IN AIRPLANE CONSTRUCTION

By E. I. de Ridder

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für Luftfahrt

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The tendency in aircraft construction is toward higher performance and greater economy. From the aerodynamic standpoint this means a minimum possible drag by streamlining, and from the structural viewpoint, saving in weight by using light metal.

Elektron is the lightest of the light metals, and as such merits our special attention because it meets the demand for lighter construction.

It is impossible to go fully into its mechanical properties and chemical composition on this occasion, but it should not be passed without at least briefly describing those characteristics which are of interest to the constructor who uses it.

Elektron, as manufactured by the I. G. Dye Industry, A.G., Bitterfeld, is a magnesium-base alloy of from 1.8 to 1.83 specific gravity, hence a third as light as aluminum alloys. The melting ~~boiling~~ point of the metal is 625° - slightly below that of aluminum. The thermal expansion coefficient is of the order of the aluminum alloys. The absolute figures for thermal conductivity, electrical conductivity, tensile strength, and modulus of elasticity (for table, see appendix) are lower than for alu-

*"Die Verwendung des Elektronmetalls im Flugzeugbau." From Jahrbuch 1929 der Wissenschaftlichen Gesellschaft für Luftfahrt.

minum or its alloys, although a comparison, which takes the specific gravity into account, yields appreciable advantages.

Regarding the chemical resistivity, it seems unfair to demand of elektron what we have been unable to achieve even with iron, that is, absolute constancy against atmospheric oxygen. Elektron corrodes, forming a grayish-white film, but this corrosion does not continue as it does in iron, the oxide film forming a protective layer against further corrosion.

Figure 1 shows an automobile wheel rim of elektron with a wrought iron disk, after having been exposed to all climatic conditions for two years. The elektron is covered with a protective film of oxide, but the iron is in an advanced stage of corrosion.

The base metal magnesium is wholly passive to alkalies, such as caustic potash, caustic soda, soap solutions, etc., but is soluble in all acids except hydrofluoric acid. Hydrous solutions containing fluoride or bichromate, such as sodium potassium and ammonium fluoride, do not attack magnesium, although it is very sensitive to chlorides.

Elektron likewise is proof against the majority of alkaline-reacting and neutral, organic elements such as trichlorethylene, carbon tetrachloride, acetone, amyl- and ethyl alcohol and, particularly, against the commonly neutral oils and pure fuels, benzene and benzol.

By changing the composition of the alloy, and mechanical

working and heat treatment, the chemical resistivity of the magnesium alloys can be materially increased. To ensure satisfactory surface protection, a simple treatment has proved very satisfactory. Pickling the metal in a nitric acid-chromate solution (bichromate of potassium 15%, concentrated nitric acid 20%, the rest water) from 1/4 to 3 minutes (depending on the size of the metal), followed by washing and drying, results in a brass-colored deposit, which acts as corrosion preventative. As in all light metals, a good coat of varnish is advisable.

To give the user of elektron a general view of its possible uses, we shall touch upon the technology of this metal. Elektron is available in the form of castings, pressings, and rolled products.

For castings, two principal alloys are used:

1. AZF, which has a high internal workability, and is particularly suitable for parts subjected to abnormally high, temporary stresses, such as parts of a landing gear and tail skid. Thus, Figure 2 depicts a landing gear assembly for the Junkers F 13. The cross bars carrying the shock absorber cord are, and have been manufactured for years of AZF metal.

2. AZG, an alloy with a high yield point and bending vibration strength is particularly suited for parts subjected to high fatigue stresses, such as crank cases, etc. (See airplane engine with elektron crank case, Fig. 3).

Aside from the usual sand castings, chill and die castings

are manufactured. The size and weight of the castings are about the same as for aluminum castings. The standard minimum wall thickness is 4 mm - in special cases for smaller pieces, 3 mm. Forged and wrought material is made from:

1. AZM alloy, which constitutes the most important material in aircraft construction as extruded profiles;

2. AM 503 - This alloy is malleable and is used for pipes and fittings of fuel tanks;

3. V 1 - especially suitable where hardness and ultimate crushing strength is considered more important than tenacity.

Figure 4 shows as example, the crank case in AZG metal and the polished and hardened cam shaft bearing in extruded V 1 metal, where the absence of bushings will be noted. This engine is in mass production.

All sections known in the iron and steel industry as rolled profiles, are made in elektron by pressing through special form presses (extrusions). With the present equipment, sizes up to 30 × 230 mm for solid cross sections and dimensions up to 200 mm web heights and 70 mm flange width in profiles, as for I beams, can be manufactured. The lengths furnished correspond to about 25 kg. Tube sizes made at present have from 11 to 150 mm outside diameter. The minimum wall thickness of extruded profiles and tubes is 1.5 mm for small sections, and 2 mm for medium and larger sections.

Pressings and drop forgings are made at 350 to 400°C temper-

atures, where the material can be shaped very satisfactorily for pistons, connecting rods, rocker arms, cam shaft bearings, etc. Larger forgings, such as propellers, have likewise been attempted quite successfully.

As rolled material, elektron is only furnished in sheets, made from:

1. AZM alloy, and principally used for supporting parts in aircraft structures;

2. AM 503 - a malleable sheet, specially suited for fairings and fuel tanks.

The available sizes conform to the standrads of the Falu (See appendix). The sheets range from 350 mm to 630 mm width; the lengths from 2 to 3 m, with the present manufacturing equipment. Profiles made from strip can be furnished in from 0.3 mm to 3.0 mm gauge thickness.

Manufacture of Elektron Metal in the Shop

Basically, elektron does not require melting and subsequent shaping within the aging limit, followed by annealing as is necessary with aluminum alloys.

On delivery elektron strip has its final mechanical properties. Appropriate annealing does not lower its tensile strength.

In principle, elektron should be hot-worked, although cold-working is possible to some extent. The best temperatures for

the AZM composition in sheets are from 270 - 300°C

AM 503	"	"	"	"	"	270 - 330°C
Z 3	"	"	"	"	"	270 - 300°C

and for V 1, AZM and AZ 31 in extrusions are from 270-300°C. At these temperatures elektron sheet can be worked like soft annealed aluminum. The permissible bending radii are equal to twice the strip thickness, for strip over 2 mm = 1.5 to 1.8 times the thickness. For working in the vise the open flame (gas flame or acetylene with compressed air or blow torch) can be used.

The suitable temperatures can be determined by coating the strip with machine oil (flash point about 300°C). As soon as the oil begins to flash, the correct temperature has been reached. Vise and chuck should be heated during working. For repeated working, as for profiles, or in drop forging, muffle furnaces have proved very satisfactory. In rare cases the strip may be clamped in wood or asbestos chucks, where heating the latter becomes necessary.

Figure 5 shows the fuselage and engine cowling of a two-place sport airplane made from a wooden pattern. For cupping, it is best to heat the tools to 400-500°C; the use of palmine is advised. Parts intended for especially high ductility are made by first welding the shaped parts and then finishing the cupping. The strip profiles used in aircraft can be made by hot-drawing. For straight profiles the matrices must be inclined

toward the direction of drawing. Figure 6 shows the manufacture of an intricate profile. The strip is drawn through matrices a and b. Both are connected by a solid piece e, and the whole is tipped at angle α. In this process the section a is shaped into b; then it is drawn through matrices c and d, where it attains its final shape. For lubrication a mixture of 1/3 hot vapor cylinder oil and 2/3 machine oil or equal parts of beeswax and mutton tallow can be used. Owing to the thermal expansion of the strips and of the drawing tools, the matrix should have sufficient clearance (up to 0.2 mm). For thicknesses up to 2 mm, the drawing speed is from 4 to 5 m/min., and 3 m/min for over 2 mm. Drawing is economical for 0.3 to 3 mm strip thickness.

In special cases, as for smaller profiles, or where it is possible to cut the profile length edges, the cut-off method can be employed. Hot-working requires heatable cutting machinery or, at least, heat insulating hardwood or asbestos chucks.

The suitability of elektron metal for fairings and tanks (gas and oil tanks) brought up the question of welding. It was found that alloy AM 503 was very weldable when a special welding flux was used. The seams themselves when hot, can be worked like the strip. Butt-welding is used because it is the only method by which it is possible to remove the oxide film. Figure 7 shows some correctly and incorrectly welded seams, and Figure 8 shows how the correct adjustment of the burner can be checked.

The mixture ratio of oxygen to acetylene is plotted against the strip thickness of magnesium base alloys and iron when welded. Figure 9 gives the discharge velocity in the burner plotted against the strip thickness. The nozzle orifice is of $\frac{1}{2}$ to 1 mm diameter. For strip thickness of 0.6 to 1 mm the oxygen feed is about 0.2 to 0.25 l/min.; over 1 mm, it is 0.5 to 0.6 l/min.

Riveted joints are made with the MG 5 alloy developed from an aluminum basis. The rivets have a shear strength of 22 kg/mm, an elongation of 26%, and can be cold-driven.

For low-stressed parts, pure aluminum rivets are practical. But for average and high-stressed parts the MG 5 rivets should be used. The crushing pressure in the strip ranges between 45 - 55 kg/mm², depending on the strip thickness.

A number of structural parts, which are only slightly shaped can be manufactured cold. In exhaustive tests on possible cold-working, the following bending radii for simple bends were set up:

AZM	strip	thickness	0.6	mm -	bending	radius	3	mm
AZM	"	"	1	"	"	"	7	"
AZM	"	"	1.5	"	"	"	11	"
AZM	"	"	2	"	"	"	20	"
AM 503	"	"	0.6	"	"	"	2.5	"
AM 503	"	"	1	"	"	"	7	"
AM 503	"	"	1.5	"	"	"	11	"
AM 503	"	"	2	"	"	"	20	"

A round disk of 500 mm diameter made of AM 503 soft can be cold-bent 25 mm, and 10 mm if made of AZM alloy.

Figure 10 shows the assembly of an engine cowling and propeller fairing, where the various parts are first welded and then shaped.

All development in conventional constructions in light metal until now are based on the kinds of structural materials. The decisive factors for such constructions are:

1. Physical and chemical properties, as well as strength;
2. Workability;
3. Behavior of the material under special operating conditions.

For elektron alloys it was therefore imperative to develop special construction methods. It is common practice to express the utility of materials in figures of merit or quality, as connoted in Figure 11, which represents a comparative tabulation of figures of merit for tensile strength and yield limit. The diagram yields in natural scale the structural weights of any of these materials under tnesile stresses, assuming equal tensile strength. The aluminum base alloys being best known, the data on weight saving was based on it. Elektron shows a saving in weight throughout, even if the yield points are used as basis.

Figure 12 is a comparative compilation of the figures of merit for structural components with respect to their bending-vibration strength. The given weight savings pertain to cast aluminum and duralumin as basis. Again elektron makes the best showing.

In Figure 13 we tabulate the figures of merit under compression and buckling. Based on a report of Wagner (Zeitschrift für Flugtechnik und Motorluftschiffahrt, 1928, page 243), we compared elektron with duralumin and steel. In Wagner's report it was

stated that profiles and plate walls stressed in buckling or bending constituted about 90% of the entire wing structure. One column gives Tetmayer's figures for AZM alloy; the best for pressed profiles, the other for sheet.

Lastly, we see on Figure 14 a comparison of structural components with equal distortion stiffness and equal notch tenacity. The data given in the diagram for distortion strength applies equally to the shear strength, although to a lesser extent, because the shear stresses in the conventional constructions with web stiffeners and sheet covering are so low that the shear strength of the elektron is amply sufficient. Moreover, the shear induced by riveting is taken up by the crushing pressure, which amounts to 45 to 55 kg/mm² and which, converted to figures of merit, admits of a saving in weight relative to the other materials.

Figure 15 shows the load test of the end rib of a Rohrbach wing, based on the relative data for duralumin and lautal as given by Brenner in the D.V.L. (Deutshe Versuchsanstalt für Luftfahrt), Report No. 89. The few changes include added gusset plates and geometrically larger profiles. But even with this increased volume in material the weight of the elektron rib is lower, although its absorbed ultimate load is higher. Notwithstanding the fact that, strictly speaking, the ratio of specific weight to ultimate load in the diagram is only theoretically important, it nevertheless becomes apparent what weight advantages

elektron metal has to offer for parts subjected to stresses.

Figure 16 shows an airplane seat of elektron. With only minor changes from duralumin seats, the elektron chair is 23% lighter and 10% stronger. In subsequent development a more suitable type of construction was inaugurated, as exemplified in Figure 17, which also is 23% lighter and of greater strength. The manufacturing cost in both types were 4.5 : 1.

For welded sheet covering and for fuel tanks, special structural methods were developed which show what may be accomplished with a material if its own particular characteristics are used to best advantage, particularly with respect to lower manufacturing cost and lighter construction consistent with safety.

We have already stated that butt-welding was the only suitable method of welding. In the manufacture of fuel tanks the partitions as well as other inside stiffeners were developed from T fittings, as shown in Figure 18b. They are made of pressed AM 503 T sections, and butt-welded to sheet a. The stiffeners c, which may induce stresses in the direction of d, are riveted to the end flap. The advantage of this method is the absence of unfavorable stress distribution and assurance of tight riveted seams.

Figure 19 shows various inside tank fittings, which may be equipped with eyes or small support blocks for point support of the tank. Often it is necessary to use anchors or tie rods as exemplified on Figure 20. All other fittings are turned from AM 503 pressings and butt-welded as shown on Figure 21.

a is the tank wall, b the fitting used for pipe connections, c an interchangeable liner, d the lock nut, and f the tightening washer.

Figure 22 shows the standardized construction of an elektron fuel tank which embodies all previously described characteristics; Figure 23, the open wing tank of a Junkers airplane; and Figure 24, the same type of tank for an Avia airplane, manufactured under Fokker license. The weight of 35 kg in brass without partitions was reduced to 17 kg in elektron with partitions. The curves in Figure 25 show the specific weights of tanks made of brass, or other conventional materials, and elektron with respect to liter volume.

Figure 26 exhibits a small rowboat, built in 1927, and which, after two years of hard usage, shows no sign of damage, even though it has not been given a coat of varnish since it left the factory. The bulkheads are open sections, all parts were varnished before riveting, the brass bearing for the rudder was insulated with wood which had been previously impregnated with tar, all hollow places where water could collect were avoided, and a tarred strip of linen made the rivet seams watertight. The boat is 6½ meters long, 97 centimeters wide, carries four persons, and weighs 30 kilograms.

In this connection it may be of interest to discuss briefly the elektron castings developed and in use for years in airplanes. Thus, Figure 27 shows the BMW airplane engine with its

elektron crank case. In high-stressed crank cases it is particularly important to avoid all abrupt changes from thin to thicker material, sharp curves, or localization of stresses.

The extent of practical application to aircraft construction and the results achieved become readily apparent on the Savoia flying boat with two 500 hp Isotta-Fraschini Asso 500 engines, shown on Figure 28, and with which Pinedo crossed the ocean twice. That this engine has proved successful for hydroplanes is borne out by the fact that about 2000 are in practical use to-day. Another striking example (Fig. 29) is the 1000 hp Isotta-Fraschini with crank casing, valve cover, carburetor manifold, cam-shaft support, etc., of elektron.

Figure 30 shows a cast elektron airplane wheel, in mass production for the Junkers type G 31, and Figure 31 shows part of a cast elektron wheel, standard for Albatros and Dornier airplanes.

Figure 32 is the cast elektron shock absorber leg for Junkers G 31 (mass production), and Figure 33, a Junkers tail skid. Figure 34 is an engine cowling for the Junkers F 13, used for over a year, and 24% lighter than a duralumin cowling.

Figure 35 shows the engine cowling and the propeller fairing of an Albatros; Figure 36 depicts an Albatros biplane with propeller fairing, engine cowling, fuselage and landing strut fairing, pilot's seat, observer's seat, etc., of elektron metal. The airplanes made by the Letov Company, Prague, likewise show liberal use of elektron.

Figure 37 shows the fuel and oil tanks for Klemm sport airplanes, and Figure 38, a series of larger wing-nose tanks, as installed in the Breda airplanes in Italy. Figure 39 shows a Junkers F 13 type wing tank, whose weight, previously of brass, was 17.7 kg, as compared to 6.7 kg in elektron metal.

After a series of tests on airplane seats made by the D.V.L., which affirmed to lower structural weight with higher ultimate load, elektron seats were produced in series and delivered to the industry. Various seats are shown in Figure 40, to be installed in BFW airplanes. A seat weighs 3.5 kg, and withstands an ultimate load of 450 kg. Figure 41 shows one aileron of a two-place Raab-Katzenstein sport airplane, in use for over a year.

A representative example of elektron in highly stressed structural components, is the engine bearer for a 40 hp Salmson-Klemm sport airplane (Fig. 42). Excepting the four-corner fittings and the mounting ring, the entire bearer is of elektron. Figures 43, 44, and 45 represent experimental wing structures in elektron; one for fabric covering, the other for metal covering, and the last wholly of elektron metal.

The possibilities of elektron metal in aircraft construction are enhanced by the marked saving in weight, which ranges between 10 - 30% with respect to the conventional kinds of materials used. What this means for the airplane industry regarding increase in useful load, can be seen at a glance on Figure 46.

Taking advantage of the present state of development with

elektron metal, the industry can effect a saving of 15% in empty weight. It would mean a higher pay load which, for the conventional types of commercial airplanes, ranges between 40 - 70%.

A p p e n d i x

TABLE I: Mechanical Properties of Elektron Alloys

1	2	3	4	5	6	7	8	9
Alloy symbol	Color symbol	Details of test bar	Supplied as	Propor-tional limit 0.02% kg/mm^2	Yield point 0.2% kg/mm^2	Tensile strength kg/mm^2	Elonga-tion %	Reduction of area %
A Z G	yellow white	sand cast	Castings of all kinds	about 4.5	10-12	15-18	2- 5	about 7
				Remarks below	(p. 18)			
A Z F	" green	" "		about 3.8	about 9	17-20	4- 6	" 9
A Z F	" "	chill cast		" 4.3	" 10	20-23	6-10	10-14
V 1	" blue	spray "		" 5.0	" 12	10-17	about 2	about 5
AZ 31	" black	sand "		" 2.8	" 6.5	17-20	6- 8	" 9
V 1	blue	extruded	Bars, profiles, tubes, extrusions	19-21	25-28	34-37	7- 9	9-12
V 1 w	blue red	extruded, annealed		19-21	24-26	34-37	10-12	13-18
V 1 h	blue yellow	extruded, hardened		22-24	26-30	38-42	2- 5	3- 6
A Z M	white	extruded		17-19	20-22	28-32	11-16	25-30
AZ 31	yellow black	"		14-16	18-20	25-28	14-17	30-35
Z 1 b	red	"		9-13	16-18	25-27	15-18	25-30
AM 503	yellow red	"		10-12	14-17	19-23	7-10	about 20
Z 3	green	soft hard	Sheets	7- 9	13-15	20-24	10-12	
						28-32	2- 3	
AM 503	yellow red	soft		about 5	8-10	19-23	5- 8	about 20
A Z M	white	soft hard		" 14	18-20	28-32	10-12	" 20
						34-40	1- 3	

TABLE I (Cont'd)

1	10	11	12	13	14	15	16
Alloy symbol	Compression strength kg/mm^2	Modulus of elasticity kg/mm^2	Brinell hardness	Notch tenacity cm kg/cm^2	Shear strength kg/mm^2	Fatigue strength	Purpose of use
A Z G	about 33	4300	53-57	about 35 Remarks, page 18	about 14	7-8	Castings
A Z F	" 32	4200	43-47	about 50	" 13	about 5.5	"
A Z F	35-38	4200	50-55	" 75	" 13	6.5-7	"
V 1	up to 30	4300	about 64	50	" 13		"
AZ 31	about 29	about 4000	" 40	about 100	" 11	about 5	Brake checks
V 1	37-40	4550	70	40	16	12	
V 1 w	35-38	4400	60	75-100	16	12	For highly stressed parts
V 1 h	40-45	4600	85-90	30	18	13	
A Z M	35-38	4500	55	120-140	14-16	about 13	Ordinary construction material
AZ 31	34-36	4300	48-50	120-140	13-15	" 10	
Z 1 b	34-36	4300	45	130	13-15	9	Can be colored by pickling
AM 503	34-36	4200	40	about 100	12-14	7-8	For welded fittings
Z 3	33-35	4250	42 60	130	13	8.5	Can be colored by pickling
AM 503	34-36	4200	40	about 100	12-14	about 7	Malleable and easily worked when hot
A Z M	35-37	4500	55 65	" 120	14-16	" 11	For light constructions

Physical Properties

Specific gravity,	1.8-1.83
" heat,	0.24
Melting point,	about 625°C
Shrinkage,	" 1.3%
Electrical conductivity,	12-18

Coefficient of Thermal Expansion

Cast alloys (AZF, AZG):	
For 20-100°,	0.0000255
" 20-200°,	0.0000271
Extrusions (AZM, V1):	
For 20-100°,	0.0000240
" 20-200°,	0.0000257
Piston alloy:	
For 20-200°,	0.0000250
Thermal conductivity,	0.32

The data for the extruded alloys depend on the degree of extrusion normally obtained in round bars up to 50 mm diameter; larger profiles show slightly lower strength figures. The data for the sheets are valid for thicknesses up to 1 mm; thinner sheets show slightly lower strength factors.

Remarks

The figures for sand cast are based on many tests. The following values are determined on sand cast tensile test bars:

AZF: yield point, 9 kg/mm^2,
ultimate tensile strength, 19-22 kg/mm^2,
elongation at rupture, 6-10%.

AZG: yield point, 11 kg/mm^2,
ultimate tensile strength, 17-20 kg/mm^2,
elongation at rupture, 4-6%.

AM 503: Although the corrosion resistance was raised at the expense of elongation, the metal is easily hot-worked.

TABLE II: Tubes - Available Sizes

Inside diameter,	8-50 mm,	with minimum thickness of	0.8 mm
" "	50.1-80 mm	" " " "	1.0 "
" "	80.1-100 "	" " " "	1.2 "

Outside diameters on demand.

Dimensions below 8 mm inside diameter on demand.

Tolerances (extrusions)

In outside diameter: ± 2.5% (minimum ± 0.25 mm)

In inside diameter (minimum tolerance only) to 20 mm ⌀ - 0.5 mm
20-60 " ⌀ - 1.0 "
over - 1.5 "

For Drawn Material

In outside diameter: ± 0.1 mm

In inside diameter to 20 mm ⌀ . . . . ± 0.1 mm
from 20-60 mm ⌀ . . . . ± 0.15 "
over ± 0.15 "

Due to the fact that tubes in hot pressing may become slightly eccentric, the following tolerances in wall thickness are permissible, which also define the eccentricity

For Wall Thicknesses:	0.8- 1.4 mm	± 0.2 mm
" " "	1.5- 2.0 "	± 0.25 "
" " "	2.1- 5.0 "	± 0.5 "
" " "	5.1-10.0 "	± 0.75 "
" " "	10.1-20.0 "	± 1 "
" " "	over 20.0 "	± 1.25 "

TABLE III: Sheets (Sizes and Tolerances)[1)]

Thickness[2)]	Manufactured widths[3)]					Maximum lengths delivered[4)]	Width		Length		Weight per m²
	mm 350	mm 400	mm 500	mm 600	mm 630		Sheets	Strips	Sheets	Strips	
	Tolerance in thickness[5)]										
mm	mm	mm	mm	mm	mm						kg
0.3	±0.03	*	*	*	*	2000	Tolerance −30 mm to +10 mm	Tolerance 5 mm In strips the tolerance is agreed upon for each case	Delivered in factory lengths, but not under 100 mm for sheets of 4 mm thickness or less; in sheets over 4 mm thickness not less than 75% of the stated maximum sizes	Tolerance +10 mm	0.546
0.4	±0.03	*	*	*	*	2000					0.728
0.5	⊙	±0.05	*	*	*	2500					0.910
0.6	⊙	⊙	±0.05	*	*	2500					1.092
(0.7)	⊙	⊙	±0.05	*	*	2500					1.274
0.8	⊙	⊙	⊙	±0.05	*	3000					1.456
(0.9)	⊙	⊙	⊙	±0.06	*	3000					1.638
1.0	⊙	⊙	⊙	⊙	±0.06	3000					1.820
1.2	⊙	⊙	⊙	⊙	±0.07	3000					2.184
(1.4)	⊙	⊙	⊙	⊙	±0.07	3000					2.548
1.5	⊙	⊙	⊙	⊙	±0.07	3000					2.73
(1.6)	⊙	⊙	⊙	⊙	±0.07	3000					2.912
1.8	⊙	⊙	⊙	⊙	±0.09	3000					3.276
2.0	⊙	⊙	⊙	⊙	±0.09	3000					3.640
(2.2)	⊙	⊙	⊙	⊙	±0.09	3000					4.004
2.5	⊙	⊙	⊙	⊙	±0.11	2500					4.550
3.0	⊙	⊙	⊙	⊙	±0.11	2000					5.460
3.5	⊙	⊙	⊙	⊙	±0.13	2000					6.370
4.0	⊙	⊙	⊙	⊙	±0.13	1700					7.280
4.5	⊙	⊙	⊙	⊙	±0.15	1500					8.190
5.0	⊙	⊙	⊙	⊙	±0.15	1300					9.100
5.5	⊙	⊙	⊙	⊙	±0.17	1200					10.010
6.0	⊙	⊙	⊙	⊙	±0.17	1100					10.920
6.5	⊙	⊙	⊙	⊙	±0.20	1000					11.830
7.0	⊙	⊙	⊙	⊙	±0.20	950					12.740
7.5	⊙	⊙	⊙	⊙	±0.20	900					13.650
8.0	⊙	⊙	⊙	⊙	±0.20	850					14.560
8.5	⊙	⊙	⊙	⊙	±0.20	800					15.470
9.0	⊙	⊙	⊙	⊙	±0.20	750					16.380
9.5	⊙	⊙	⊙	⊙	±0.20	700					17.290
10.0	⊙	⊙	⊙	⊙	±0.20	650					18.200

See footnotes 1, 2, 3, 4, and 5, on page 20.

Footnotes from page 20:

1) According to established standards of Falu.

2) Sheets under 2.5 mm thicknesses, other than given, are made on demand only. Intermediate thicknesses can be supplied in sheets of over 2.5 mm, but are not kept in stock; therefore, those in parentheses should be ordered only when absolutely necessary, due to delay in delivery.

3) Larger widths are not available; the same applies to those marked with * ; those marked with ⊙ can be delivered, but are considered as strips.

4) These are for normal widths. Narrower sizes of greater length can be obtained on special order.

5) When measuring the tolerance the measuring points should be at least 100 mm from the corners and 40 mm from the edges.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics

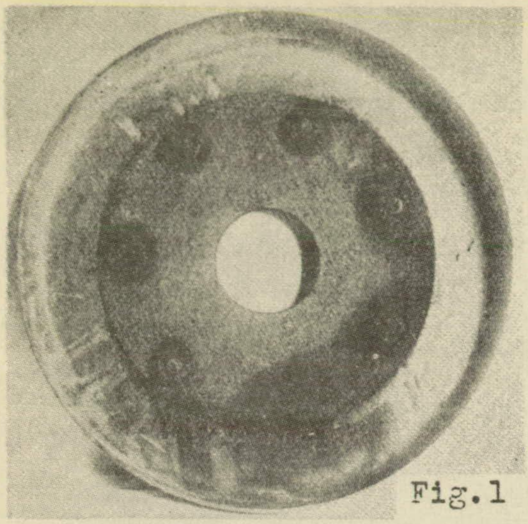


Fig.1

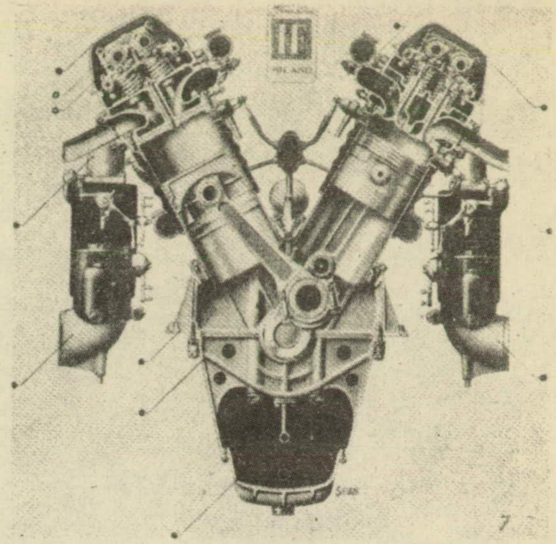


Fig.4

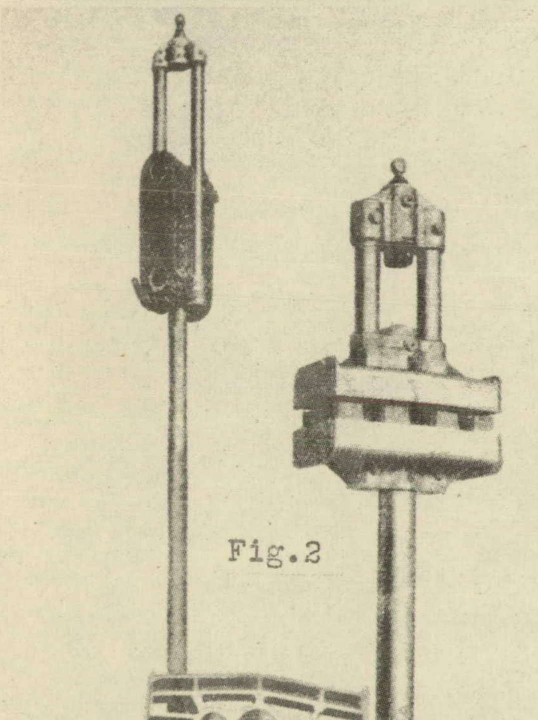


Fig.2

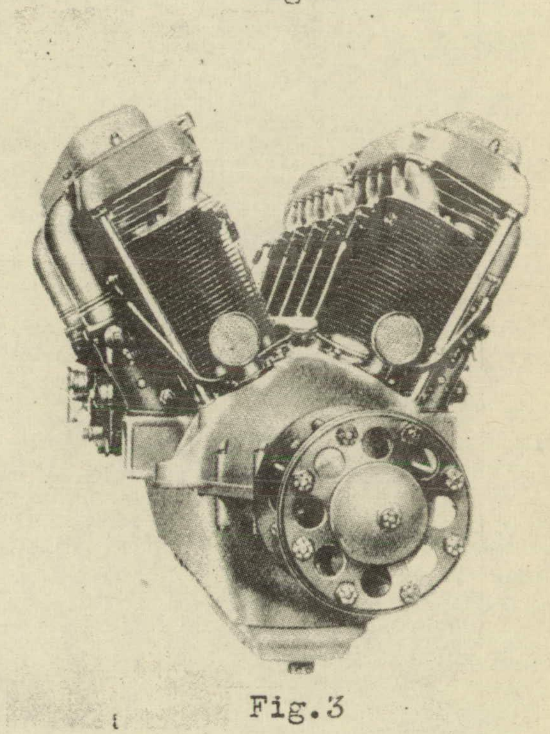


Fig.3

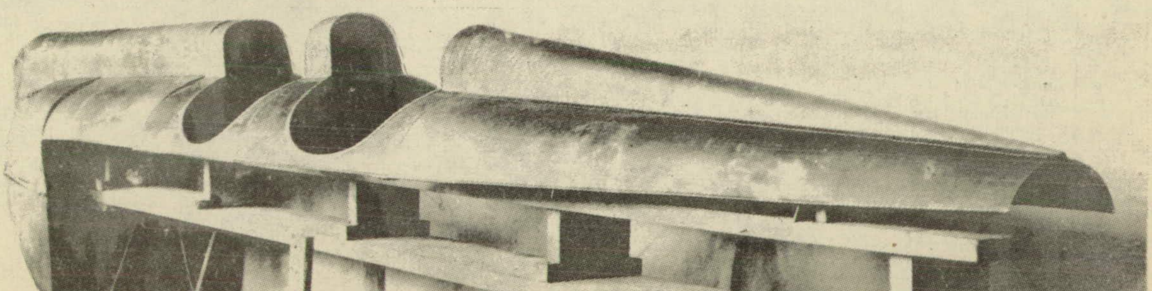


Fig.5

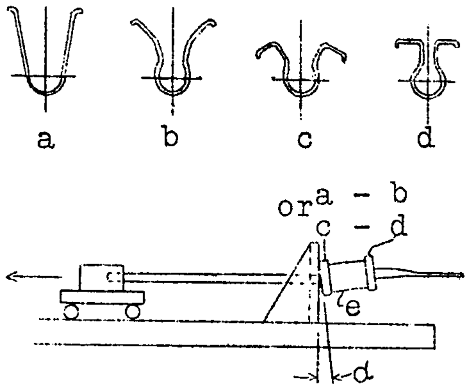

a
b
c
d
or a - b
c - d
e
d

Fig.6

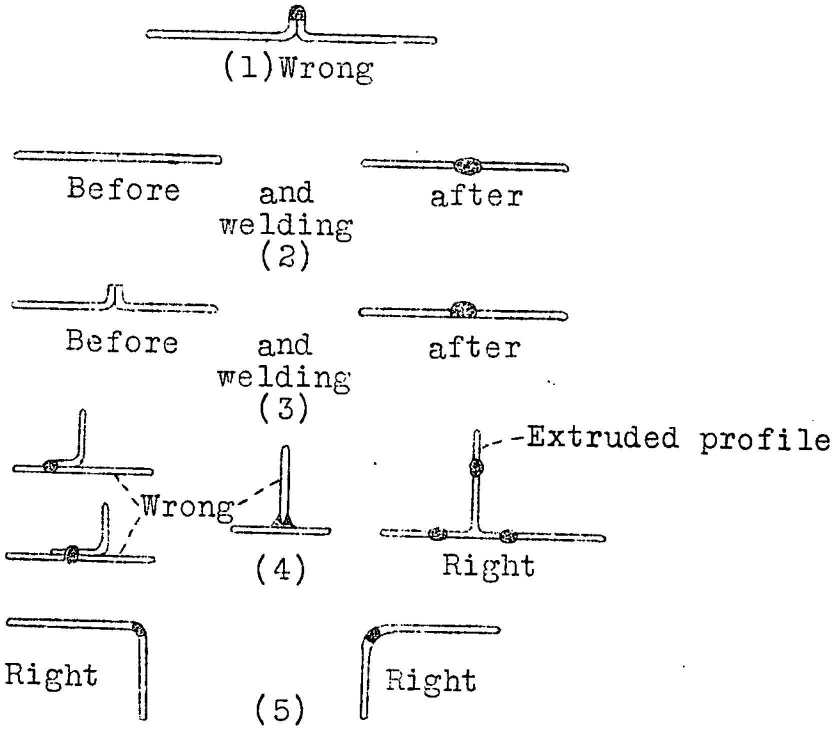

(1)Wrong
Before and after welding
(2)
Before and after welding
(3)
Wrong
Extruded profile
(4)
Right
Right
(5)
Right

Fig.7

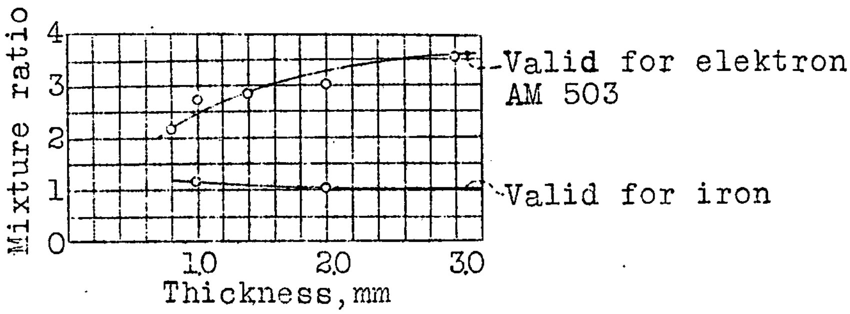


Fig.8

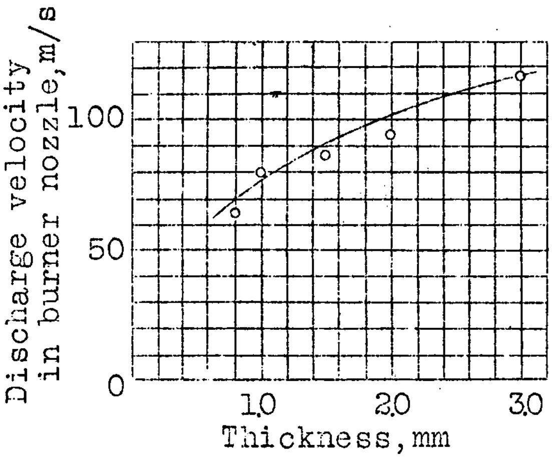


Fig.9

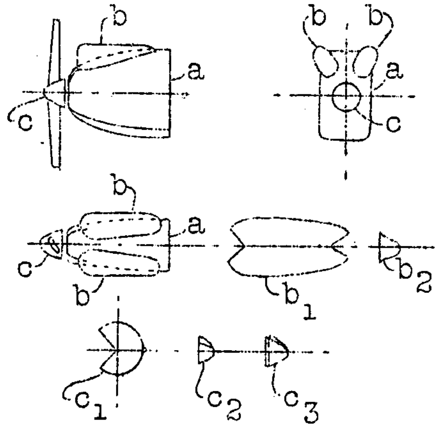


Fig.10

	Cast			High stressed sheet			Low stressed sheet		
	Elektron AZG	Aluminum	Iron	Elektron AZM	Duralumin	Lautal	Elektron AM 503	Aluminum hard	Aluminum half hard
K_z	15.0	15.0	18.0	30.0	40.0	38.0	21.0	16.0	13.0
$\sigma_{0.2}$	10.0	11.0	14.0	19.0	25.4	22.0	9.0	11.0	8.0
$\frac{\gamma}{K}100$	12.1	19.3	40.0	6.06	7.0	7.37	8.66	16.2	20.0
$\frac{\gamma}{\sigma_{0.2}}100$	18.2	26.3	51.5	9.6	11.2	12.7	20.2	23.6	32.5
Struct. weight $\sigma_{0.2}$	-30.8%	0%	95.8%	-14.3%	0%	13.4%	-14.4%	0%	37.7%

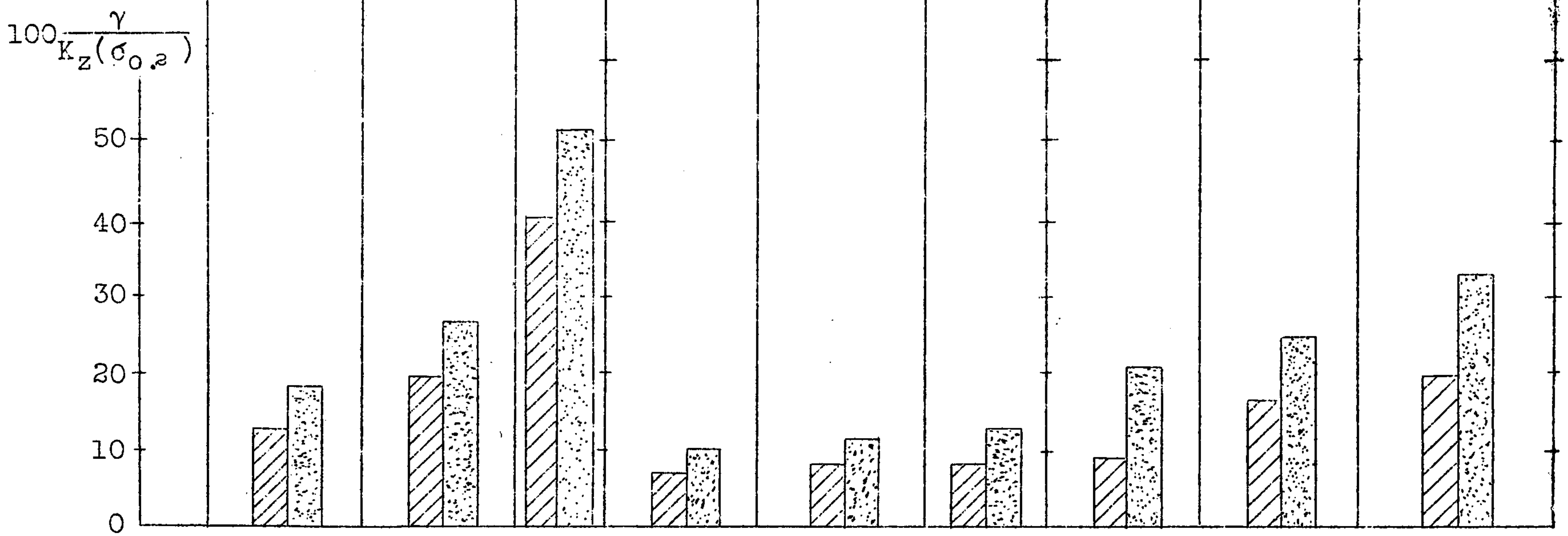


Fig.11 Figures of merit for tensile strength and yield limit.

	Cast			Construction material (bars)			
	Elektron AZG	Aluminum	Iron	Elektron AZM	Duralumin 681B ⅓	Carbon steel	Nickel chrome steel
K_z	15.0	15.0	18.0	30.0	40.0	72.0	78.0
$\sigma_{0.2}$	10.0	11.0	14.0	21.0	25.0	50.0	65.0
D_s	7.5	6.5	6.5	13.0	14.0	35.0	45.0
$100\,\frac{\gamma}{D_s}$	24.25	44.6	111.0	14.0	20.0	22.3	17.0
Structural wt.	-45.5%	0%	149.0%	-30.0%	0%	11.5%	-12.5%

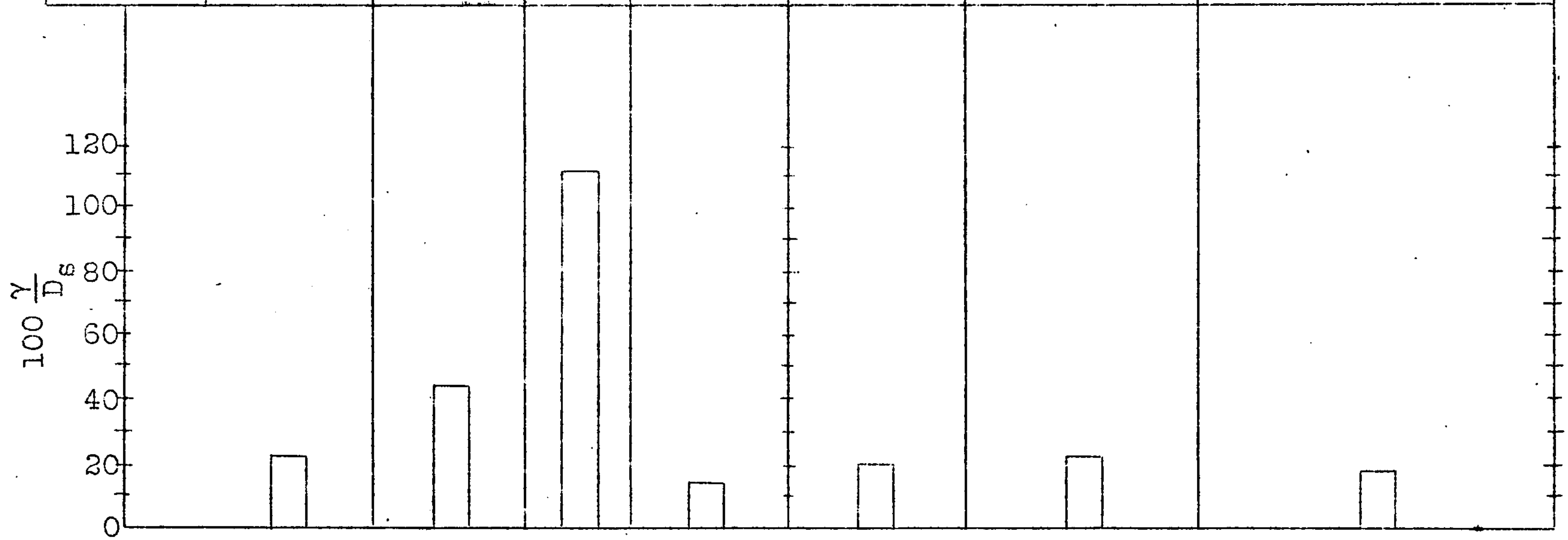


Fig.12 Figures of merit for bending-vibration strength.

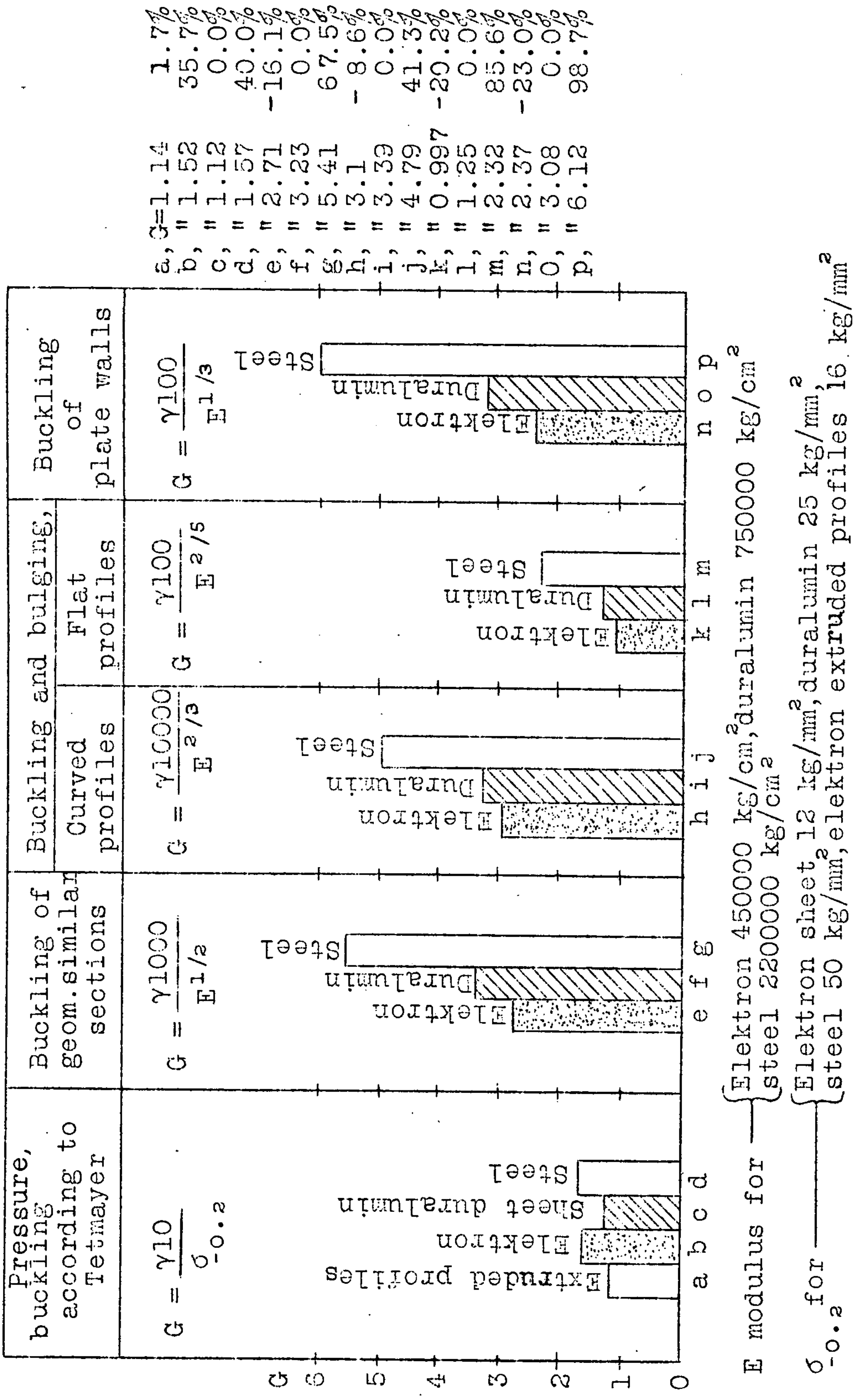


Fig.13 Figures of merit for compression and buckling strength.

Notch tenacity			Distortion strength			
	Elektron	Duralumin		Elektron	Duralumin	Steel
Notch tenacity, cm kg/cm²	120	150	Modulus of regidity, kg/cm²	170,000	270,000	830,000
$\frac{100\gamma}{\text{Notch tenacity}}$	1.515	1.865	$\frac{\gamma\,100000}{\text{modulus of regidity}}$	1.07	1.04	0.945
Structural weight	-18.75%	0%	Structural weight	2.9%	0%	-9.1%

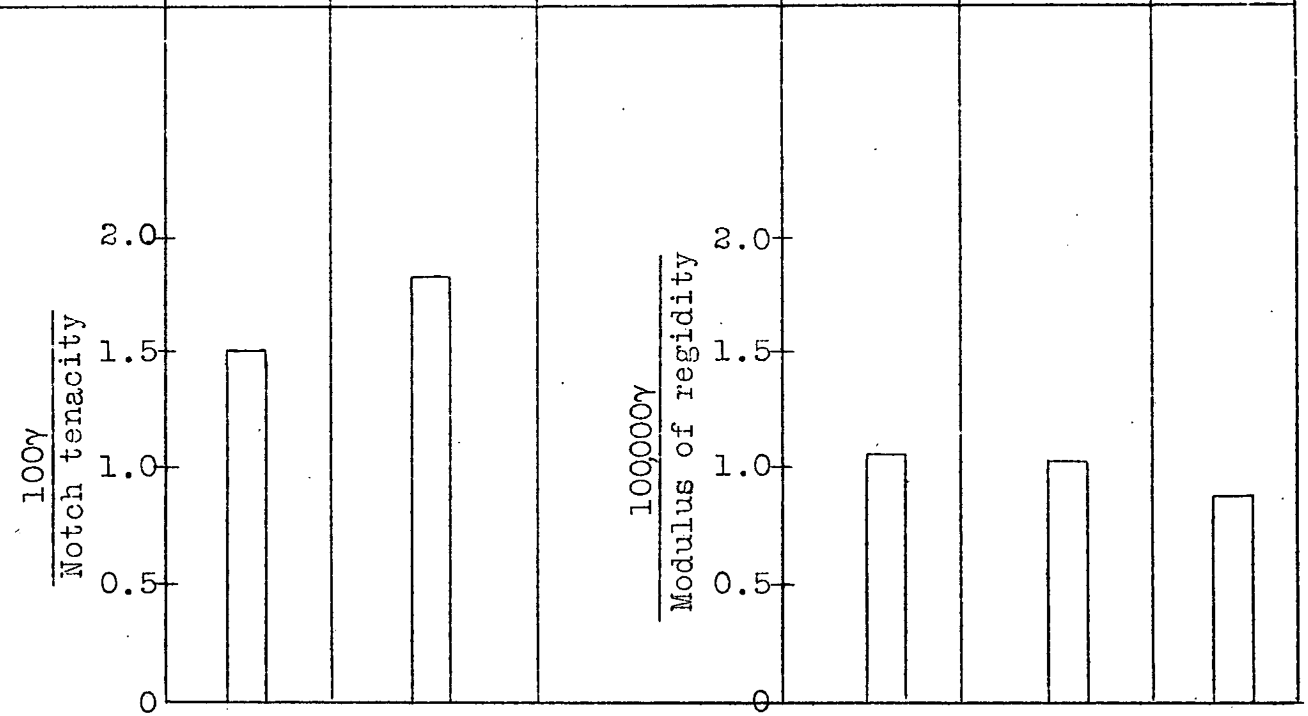


Fig.14 Figures of merit for notch tenacity and distortion strength.

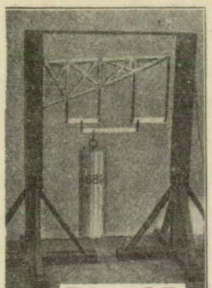
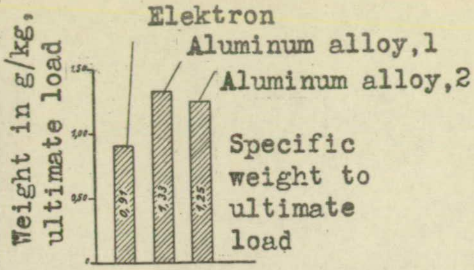


Fig. 15



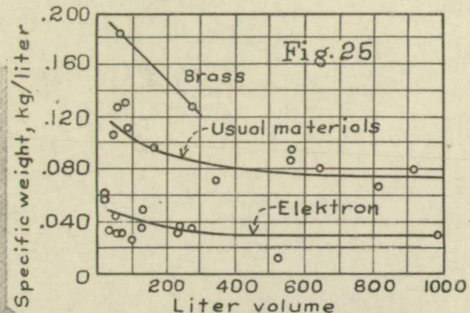


Fig. 25

Fig. 16

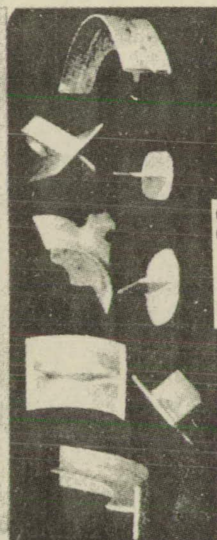


Fig. 19

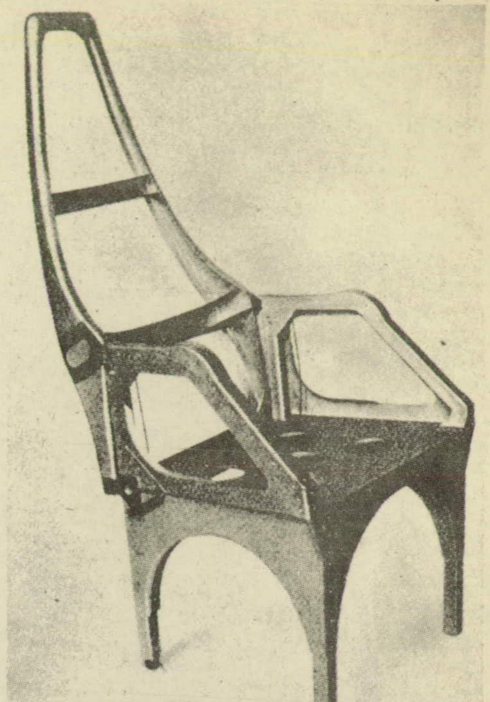


Fig. 17

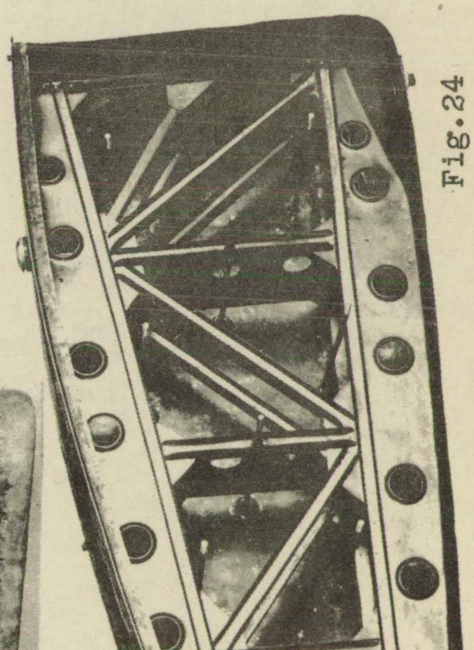


Fig. 24

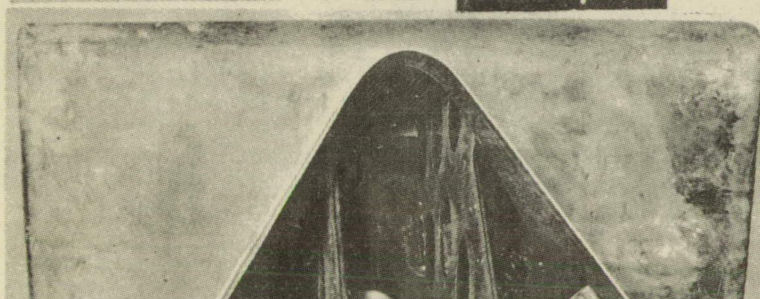
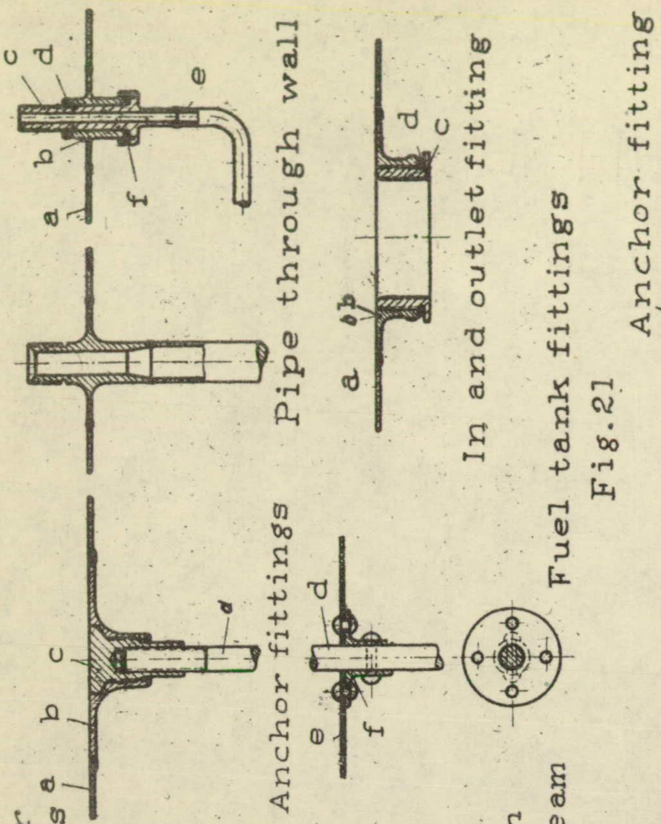


Fig. 23



Fuel tank fittings
Fig.21

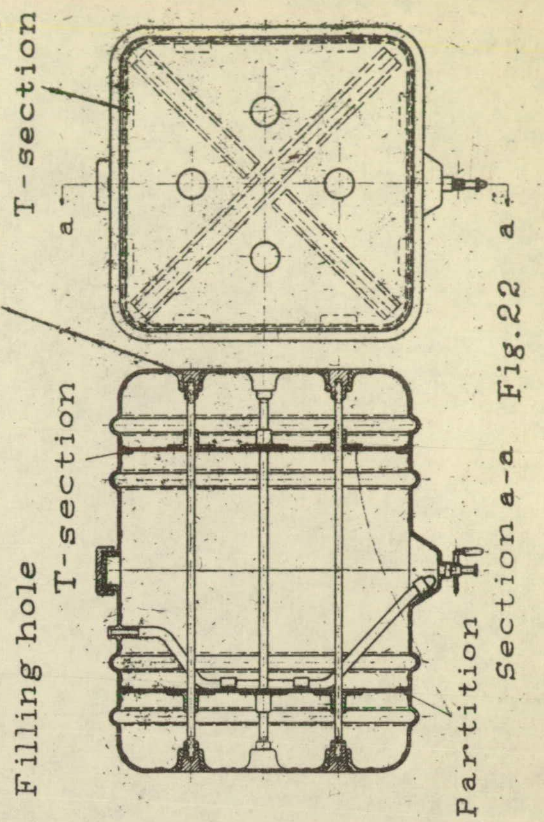


Fig.22

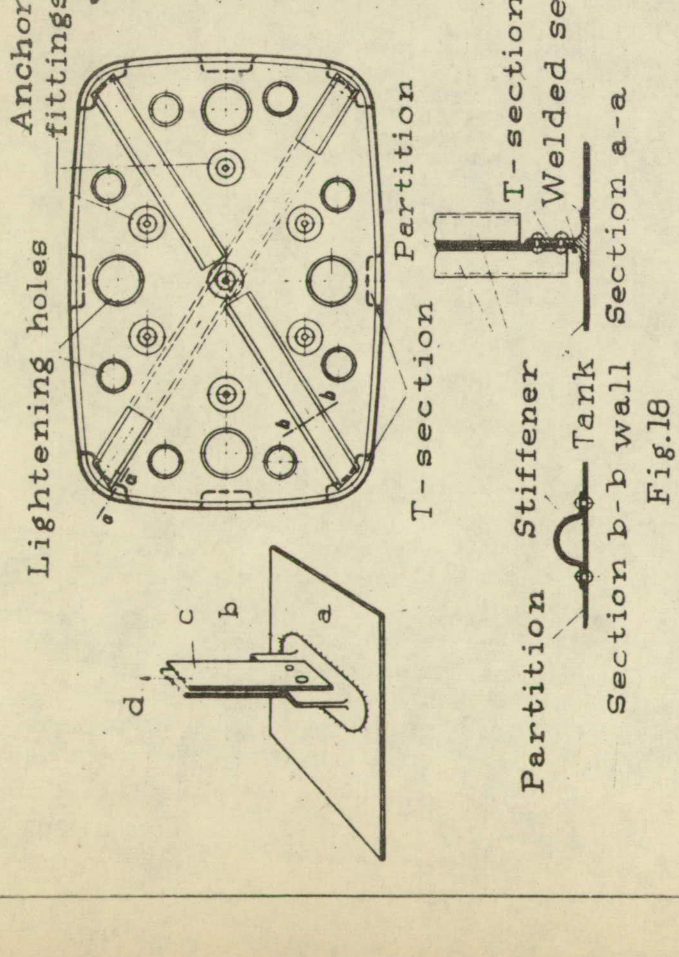


Fig.18

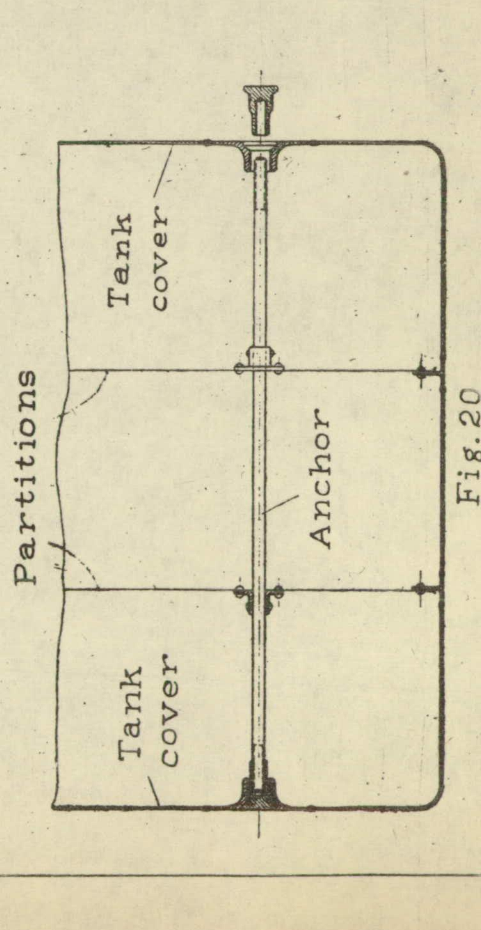


Fig.20

Fig.26

Fig.28

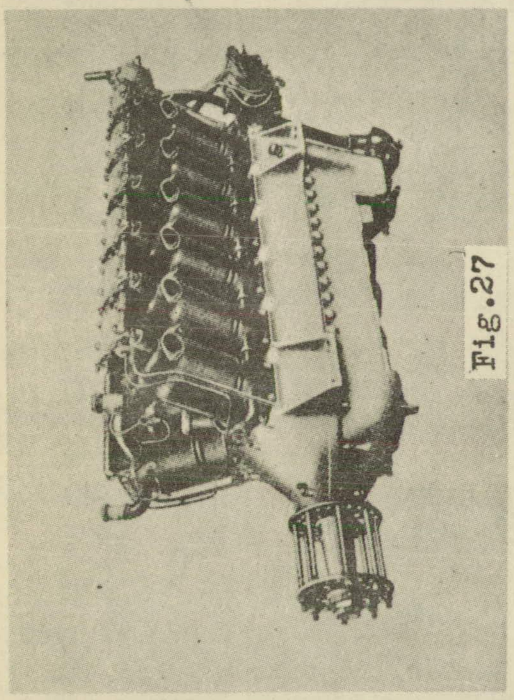


Fig.27

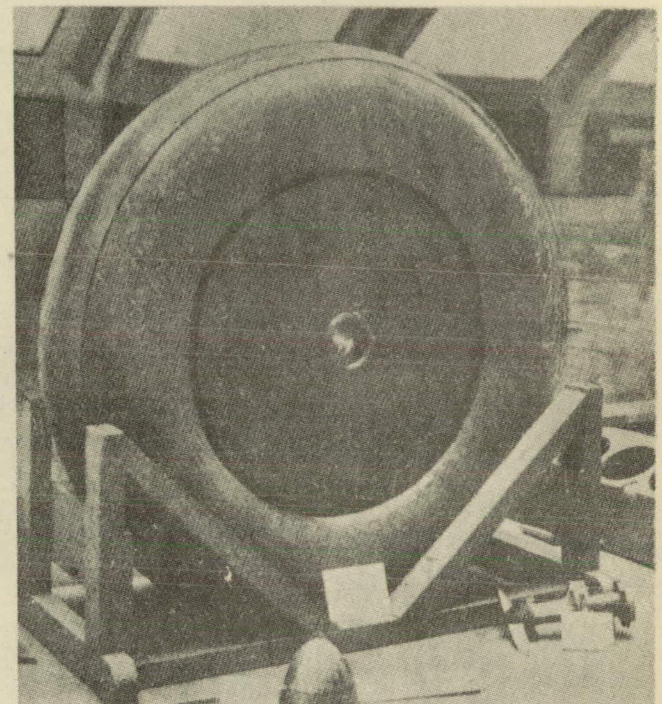


Fig.30

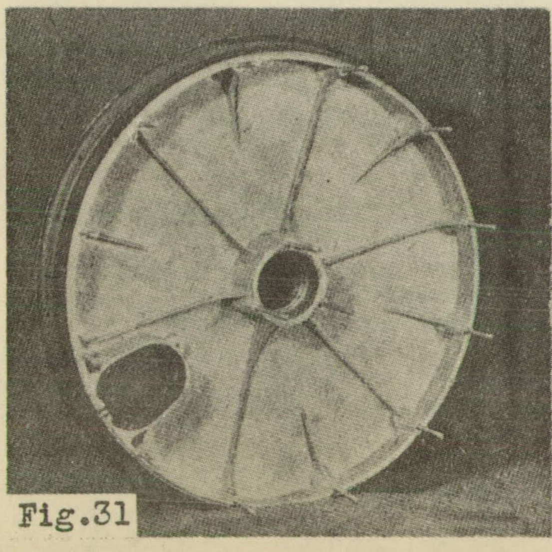


Fig.31

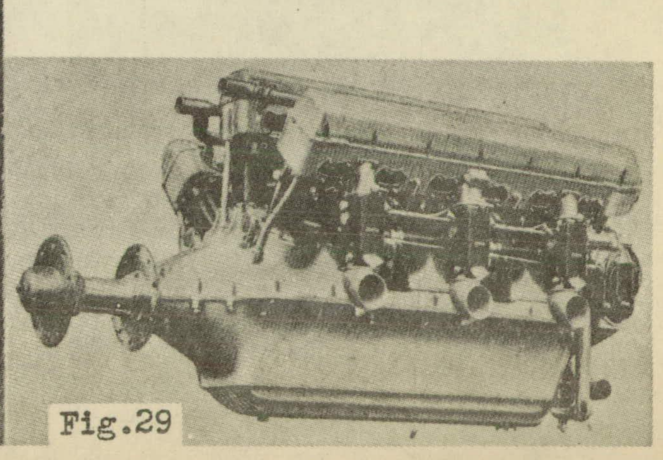


Fig.29

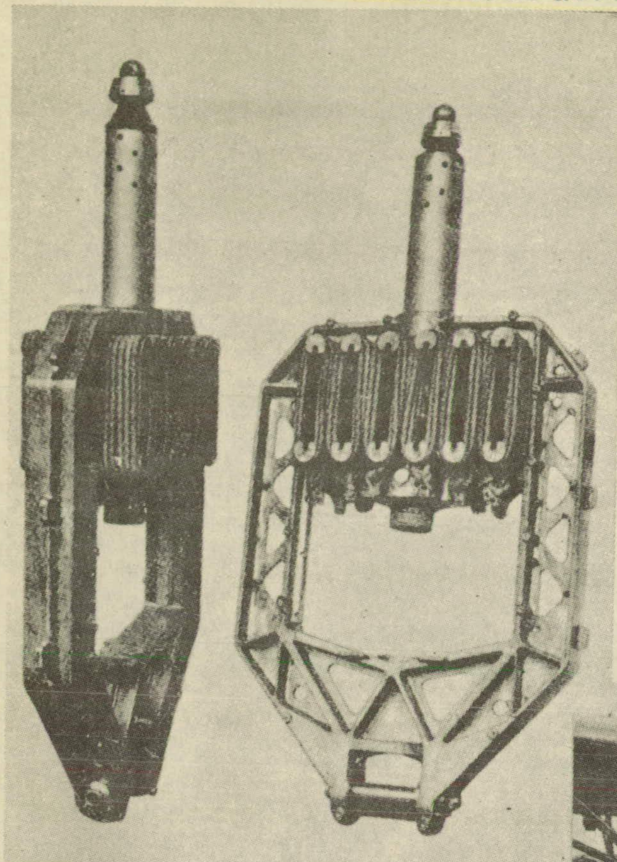


Fig.32

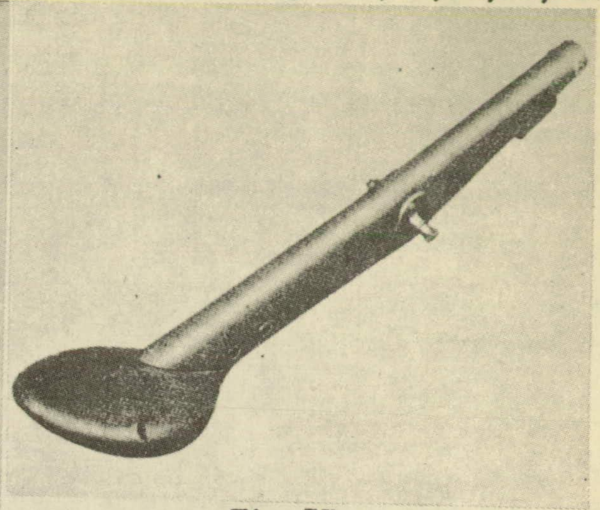


Fig.33

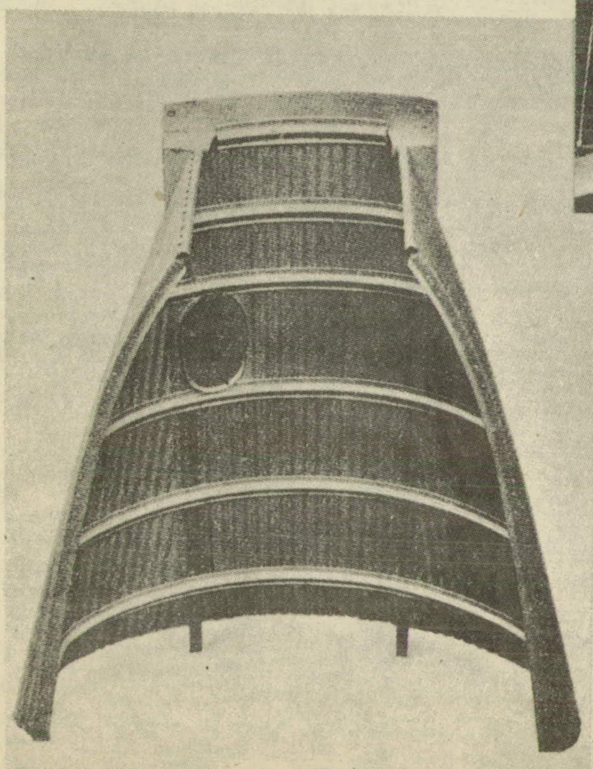


Fig.34

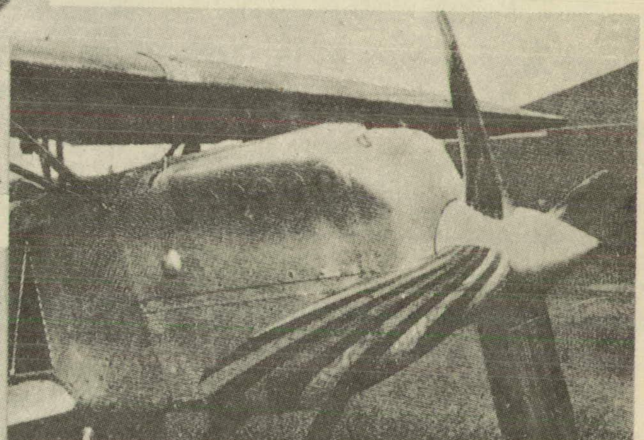


Fig.35

Fig.36

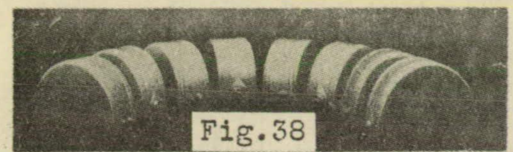


Fig.38

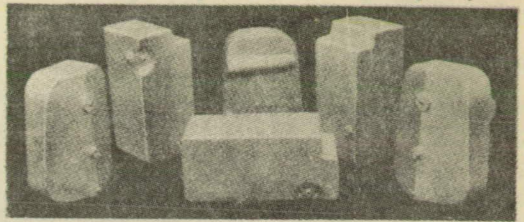


Fig.37

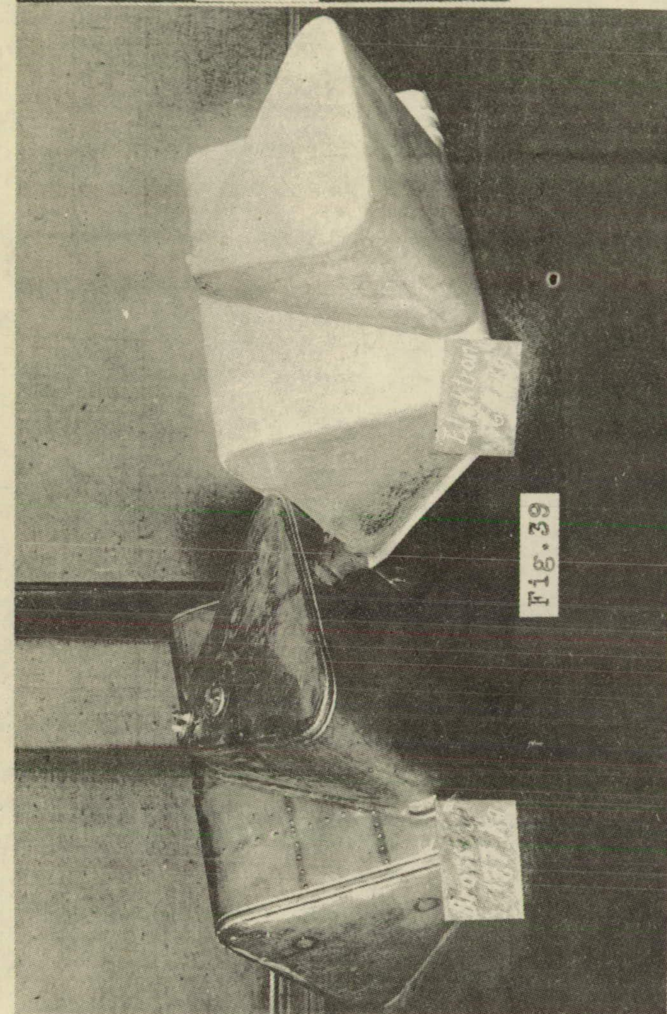


Fig.39

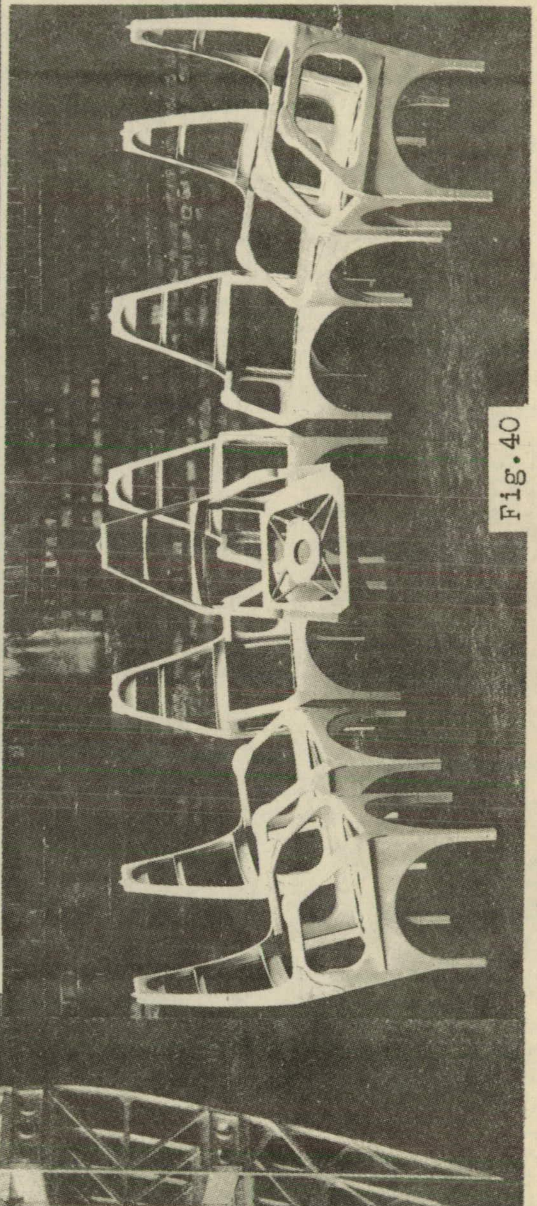


Fig.40

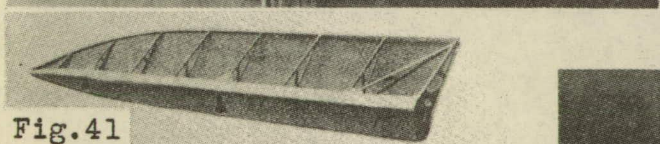
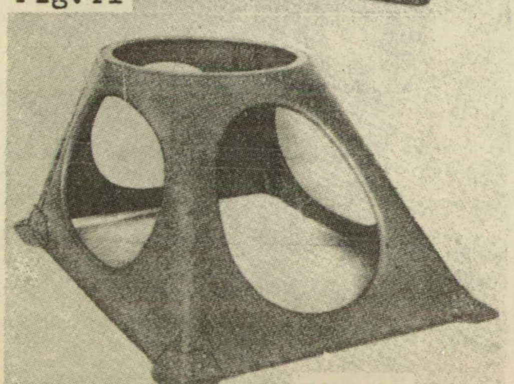


Fig.41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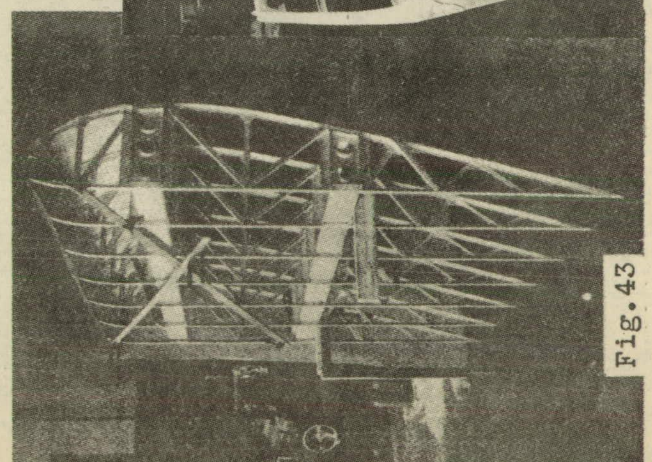
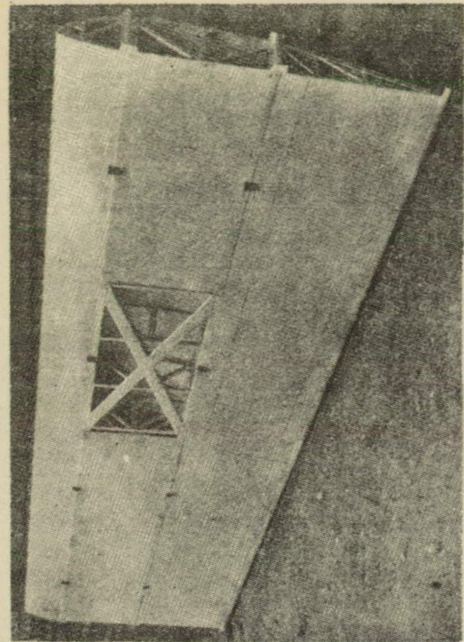


Fig.43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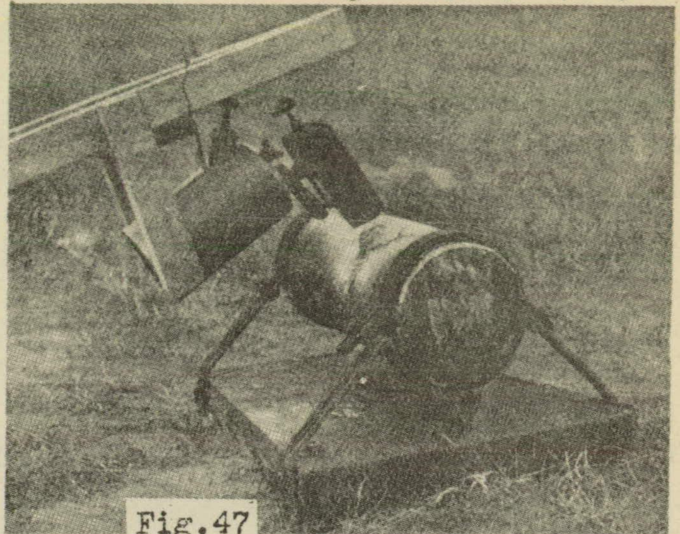
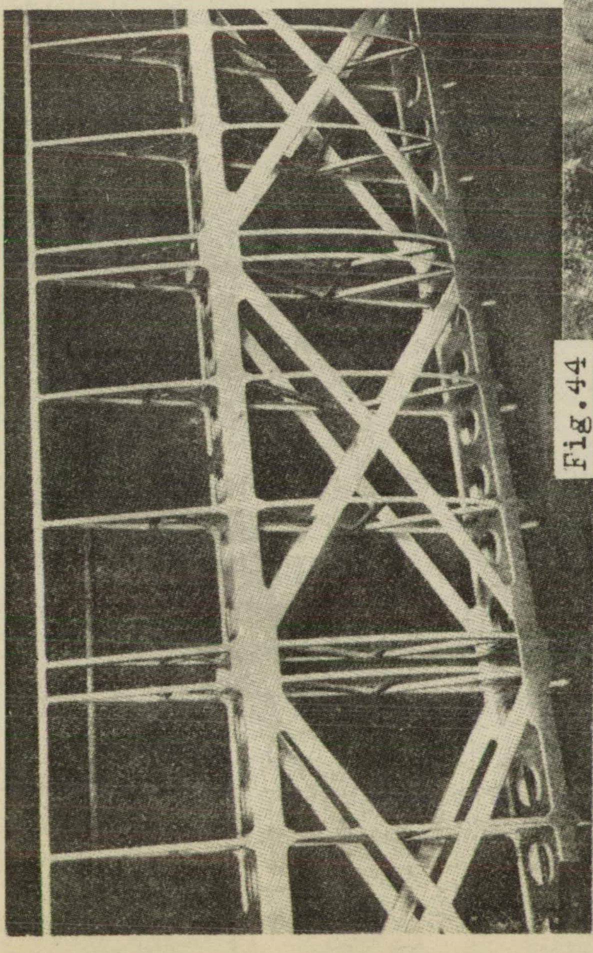


Fig.47


Fig.49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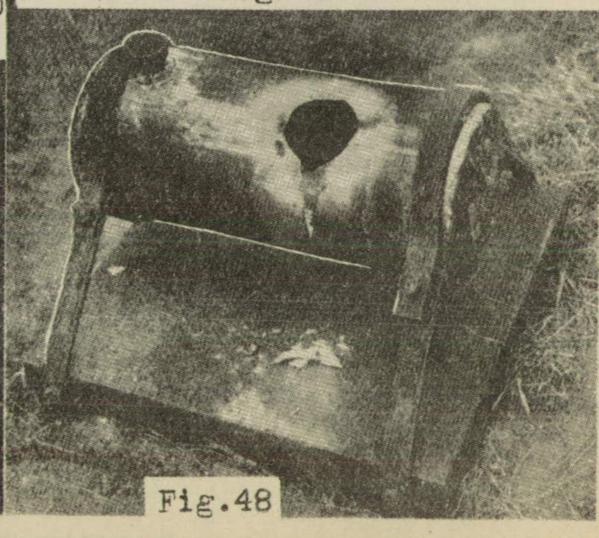
Fig.48

		Roland(RoVII)	Junkers(G31)	BFW(M20)	Dornier-Merkur
Total weight		6000	8000	4500	3600
Empty weight		3900	4400	2400	2150
Useful load		2700	3600	2100	1450
Passengers (@ 80 kg)		10	13	10	6
15% saving in empty weight		585	660	360	322
Increase in pay load	Passengers	7	8	4	4
	%	70.0	61.5	40.0	66.6

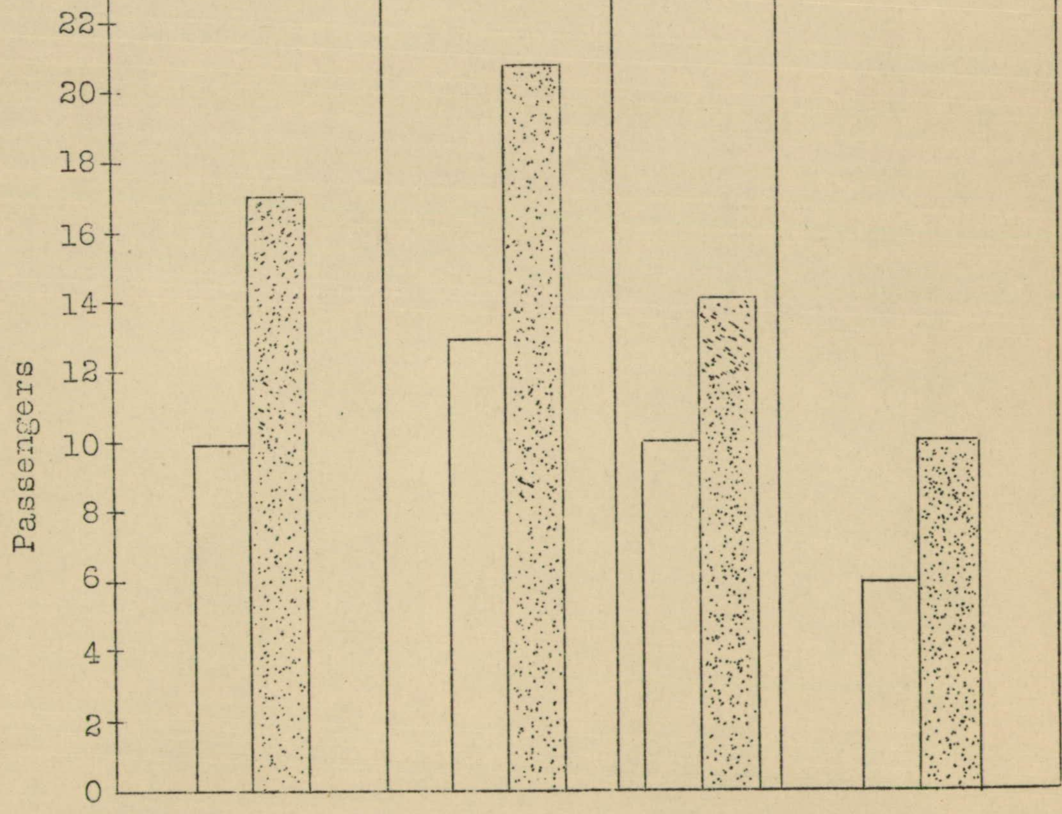

Fig.46 Increase in useful load when using elektron.